Models, High-Energy Theoretical Physics and Realism

I. Introduction - How Does Science Function? - A Description

A. Identify Some Major Characteristics

1. Kuhn - paradigms, normal vs. revolutionary science
2. Lakatos - research programs, hard core, heuristics, auxiliary assumptions
3. Laudan - problem solving vs. knowledge and truth
4. Redhead - invariant form of mathematical theory, theoretical models, stretching, excess content
5. Cushing - various types of models and their uses
6. Dirac - two routes to mathematical concepts; importance of theory over experiments for modern concepts in physics
7. Zahar - creative role of mathematics in discovery of physical theories
8. Hesse - analogy and metaphor
9. MacKinnon- traditions and personal relations in theory development; various stages (formative state, deductive unification, axiomatic reformulation)
10. McMullin - fertility
11. Ziman - public (debated) knowledge as reliable
12. Pickering - analogical recycling; interests and other sociological factors
13. Fleck - importance of social aspects of sciences - genesis and development of a scientific fact
14. Zuckerman - problem change in science
15. Woolgar and Latour - production of order, construction of facts, purchase of credibility

B. Rational vs. Sociological Aspects of Science (Justification vs. Discovery)

1. justification vs. discovery - not disjoint (Bantz, MacKinnon); no sharp distinction
2. importance of selection of facts to be explained (Brillouin)
3. creation of theories and entities
4. motivation (Einstein) - to create something which will endure (in the intellectual sphere)
5. enter the field and hold against all comers - a tested theory
6. truth, knowledge, and progress - roles in science (Laudan, Sarkar, Leplin)

C. Case Studies

1. to test various methodologies and descriptions
2. current programs in theorelical high energy physics

II. Elementary Particle Theory

A. Quantum Field Theory

1. models, exemplars, and analogies used in development (Synthese article)
2. Fermi and gauge condition
3. renormalization - consistency problem
4. Lamb shift
5. local gauge invariance - basic idea of Yang and Mills
6. color and flavor
7. unification - via the restrictive and overarching gauge principle
8. Noether's theorem

B. S-Matrix Theory

1. Heisenberg's orginal program
2. Chew-Low theory, etc. - roots of modern SMT program-bootstrap conjecture
3. heyday of the 1960's
4. philosophical considerations - Chew, Stapp
5. dual topological unitarization - Harari - Rosner, Veneziano
6. concept of order (Weissmann) - nature of SMT changed by this postulate
7. topological S-matrix theory (TSM)
   a. particle aristocracy
   b. strong, weak, and electromagnetic(?) interactions included
   c. great increase in empirical content
8. major steps in Chew's choice of topological entities
   a. planarity - mesons
   b. baryons - "sphere"
   c. polyhedra ~ unitarity
   d. strong vs. weak interactions ~ orientable vs. non-orientable surfaces
   e. Stapp's "separation" result - topological supersymmetry
   f. calculations - the difficulty

C. Possible Equivalence of QCD and TSM

1. simply valid in different domains (large $p_\perp$ vs. small $p_\perp$) - limits of some more general theory
2. one a limiting case of the other

3. equivalent to each other (Schrödinger vs. Heisenberg, etc.)

4. clews for the above

   a. quark, etc., all "found" in TSM

   b. importance of topology in both

   c. strings and 1/N expansion limit

III. General Features of These Programs

A. Case Studies in II Related to Outline in I

1. surplus structure - gauge theories: solitons, monopoles, etc.; topology in TSM

2. analogical and expertise recycling - Balazs, Stapp in SMT; Johnson, etc. in QFT (Pickering)

3. predominance of mathematical sources - charm (strangeness-changing current suppression), group theory origin of quarks, topological entities in SMT, Higgs boson

4. lots of theoretical models (Synthese, etc.)

B. Sociological (Nonrational?) Aspects of Enterprise

1. data (experiment) selection by theory; data permeable to argument

2. analogies recycled because expertise is (specific examples)

   a. composits

   b. QED analogy for QCD

3. theory selects data → support for theory - a bias (not absolute, though)

4. creation of theories and entities

   a. whole eras ruled by thought constraint (Fleck) (e.g., stability of proton until recently)

b. language of TSM has become largely that of QCD

5. can these complex and open-ended theories (such as QCD) ever really fail?

a. what if Higgs boson is never found?

b. what if neutral weak currents and charm had not been observed?

c. what if proton does not decay?

6. lots of pieces, some of which fit together into a workable theory; we create the world as we see it

7. nature of accepted explanation

C. Motivations for Theorists

1. Chew (letters, questions, etc.)

a. great scope of general principles

b. obligation (Einstein)

c. analogy with Descartes (intuit at first vs. empirical input later).

2. interest of individuals to employ expertise

a. Chew - no great ability to do field theory calculations quickly

b. Stapp-M-functions

c. Balazs-δ-function approximations

d. QCD examples

3. simplicity in terms of theory

4. general philosophical considerations

5. escape from everyday-create something to endure

IV. Realism of Theoretical Entities

A. Realist Position

1. Putman

2. McMullin

3. Leplin

B. Is Realism Reasonable?

1. Laudan

2. Fine

3. Status of central terms in several theories

a. classical mechanics and E & M - particle coordinate, $\vec{x}(t)$

b. quantum mechanics - wave function

i. a calculational device

ii. (Born's) probability interpretation

c. quantized fields

i. a tool

ii. the vacuum

iii. observability

d. SMT - amplitudes (~ observables)

e. Feynman, Landau, etc. graphs - a way of representing terms in (c) and (d)

f. topological entities in TSM - a "bookkeeping" device

4. given subjective (personal) elements of the scientific enterprise is "objective" realism still reasonable?

5. network model of knowledge

6. MacKinnon - truth of scientific claims

7. Newton's Rule IV, Book III of Principia